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Eco-security Monitoring Index System for Urban Development Zone

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Abstract

Urban Development Zones are always constructed rapidly and intensively, resulting in contingent ecological and environmental problems. This paper establishes a set of ecological-security index system for urban development and construction. It utilizes Pressure-State-Response (P-S-R) model to select frequently-used indexes, which represent the features of urban society, economy, and ecosystem environment. Through public survey and the analysis of the questionnaires, and Analytic Hierarchy Process (A-H-P) analysis, it prioritizes all the indices and screens out a set of operational eco-security index system according to the principle of monitorability. This method is applied to establish the eco-security monitoring index system for Beijing Eco-Tech Development Zone, therefore to provide basis for dynamic eco-security monitoring for the development and construction of Beijing Eco-Tech Zone.

Keywords: Eco-security, Monitoring, Indicators system, Urban Development Zone, Beijing

1 Introduction

Facing serious environmental challenges at global and local scales nowadays, ecological security has become equally important with military security, economic security, political security, national security human well-being [1-14]. The term ecological security was first proposed by the government of the United States [15]. Since then, it has been widely considered [16].Ecological Security is defined as being in the state of non-or-minimized detrimental and threatening effect on ecological environment, which is required for the living and development in a particular region, and the potential of eco-environment suffices the sustainable developing needs for human communities without devastating the eco-environment itself [17]. Urban eco-security is a crucial aspect of eco-security in general and without doubt the contributing factor to national security. It depends on the coordinated collaboration between the need of urban social-economic development and the benefit of eco-environment; not only does it satisfy the required resource for urban development, but maintain the ecological well-being simultaneously [18]. Its essence is to demand natural resource be allocated in stable, collaborative, orderly and sustainable means under the three binding factors of urban population, social-economy and ecological environment.

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Presently, scholars have done some research on urban eco-security assessment and pre-alarming system. Research on eco-security assessment indexes was mainly based on OECD's P-S-R system "Pressure-State-Response". In such, "Pressure" was direct pressuring factor of human activity upon environment, such as waste discharge, processing, density of highway-networks, coal mining; "State" referred to current state and future trend for environment, such as pollutant concentration, varieties of species. Under such circumstance, eco-security assessment study considered plantation coverage, bio-prolificacy; "Response" referred to the quantitative part of environmental policies, which evolved constantly in the process of environmental treatment. In addition, there was the UNCSD D-S-R assessment system; European Environmental Agency augmented "driving force" and "impact" and made it D-P-S-I-R assessment system [19]. Those researches focused on global environment changes and threat they brought, and on state or global and regional level, from greater scale of state, provincial, city, down to rivers, lakes, mountains, dry land, towns, villages, wetland, touring regions. Assessment methodology, having adopted broad range of relative science and numerous fruitions in research, has evolved from primitive illustration to current quantified precision judgment [20]-[23]. Above research has provided crucial experiences for building eco-security system in development zones, whereas current research results have touched little in monitoring of eco-security systems. Monitoring Index System is the basis for eco-security monitoring in general, and is different from Assessment Index System of eco-security in the sense of its dynamic and monitorability aspects. Monitoring Index must be built upon existing experiences and combined with subject research zone features and adequately operational means.

Urban Development Zone differs from other local areas in the sense that it's key-subsidiary economic region by the government. It's usually a region with much foreign investment, fast economic development, outstanding locality advantage, quite open to the outside world, highly developed. However, it also consumes enormous resource and energy. Such rapid urbanization brings unprecedented wealth to mankind, which at the other hand forces an all-out restructuring of the regional eco-system. Consequently, eco-environment protection is facing rising pressure and challenges. Some development zones have become man-made eco-frail regions, and the problematic issues of eco-security are becoming more urgent and severe than ever [24]. In order to protect eco-environment and safeguard the regional eco-security concurrently with the high rate of economic growth, an eco-security monitoring system must be built and developed to pre-alarm the recessive and deteriorating signs of environmental quality and ecosystem. Urban eco-security monitoring is the basis for urban eco-security assessment and prediction; it can send out pre-alarm for ecological crisis, which provides basis for policy makers [20].

2 Framework of Monitoring Index of Eco-Security System for Urban Development Zone (UDZ)

Correlating with the specifics of UDZs and eco-security essence, this paper established a set of Eco-Security Indexing Systems for construction of UDZs, utilizing P-S-R model. Based on questionnaires and A-H-P analysis, prioritize the indexes, we then selected a set of operational eco-security monitoring indexing system according to principles such as monitorability. See Fig 1.

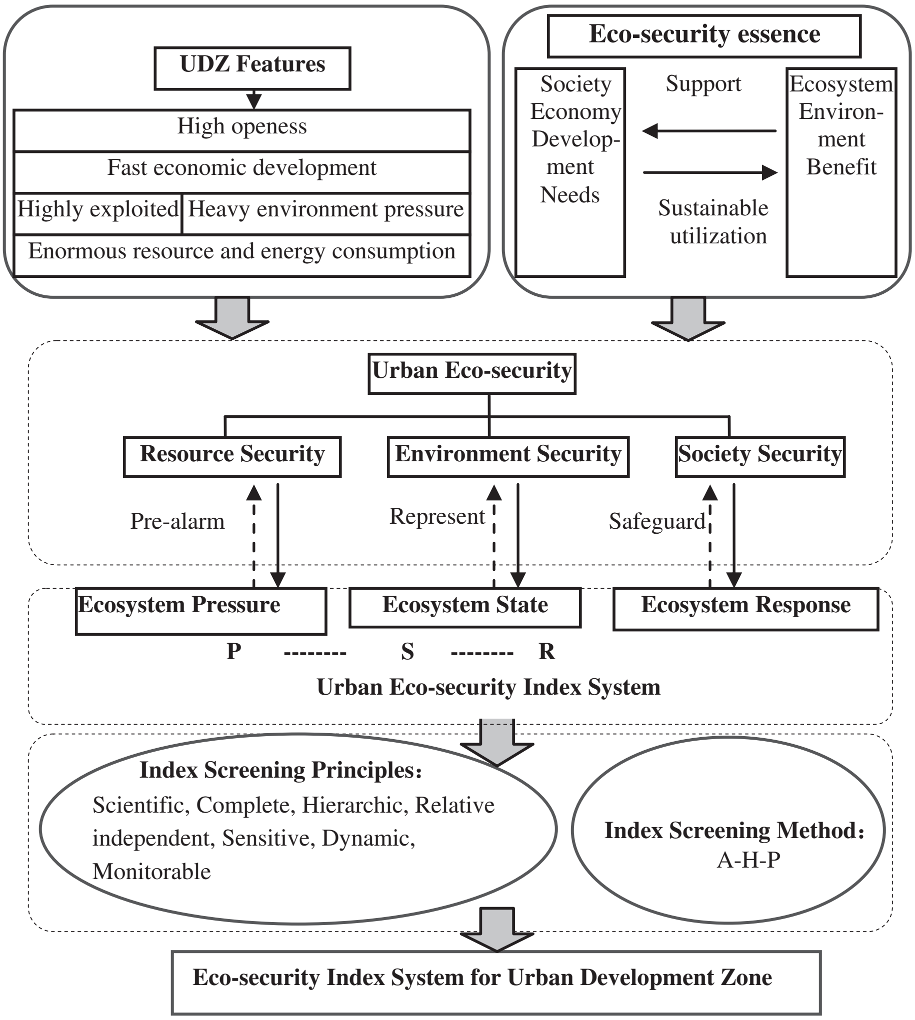

Fig 1. Framework of Eco-security Monitoring Index System for Urban Development Zone

2.1 Building Index System

Firstly, Select frequently-used indexes to represent UDZ specific issues and Eco-Security essence based on P-S-R model. P-S-R is comprehensive and flexible which reflects the indexes of human activities and those of natural environment; it adapts to macro-scopic environment phenomena which also emphasizes the impact of human activities on eco-system. This model consists of 40 core indexes, covering broad range of environment issues. “State” index is to reflect the natural environmental changes as a consequence of human activities; “Pressure” index is to expose the reasoning and potential impact due to triggered eco-security and environmental issues; “Response” index is to express human responses and capacity of overcoming eco-environment issues.

Secondly, considering research zone’s resource, social and economic conditions and major challenges, through public survey and the analysis of the questionnaires, and rating the indexes based on the results and A-H-P analysis, adjust and select an ultimate set of operational eco-security monitoring indexing systems based on the principles of screening monitoring indexes.

2.2 Principles for index screening

(1) Scientific: each index is stable and independent from one another, and able to demonstrate a specific aspect of natural resource, ecologic, social and economic status of development zones. (2) Complete: broad coverage, reflect eco-security status of development zones from various perspectives. (3) Hierarchic: correlative monitoring indexing system must be established for different urban sub-systems based on hierarchy. (4) Relatively independent: connotations on indexes are clear, documents available, easily calculable, each index is unique and representative. (5) Sensitive: changes in quality of resource and environment can be easily identified in the indexes (6) Dynamic: indexes must reflect evolution order and trend of development zones eco-security, as well as the dynamic changes of eco-security. (7) Monitorable: the monitoring index system must adapt into local environmental monitoring system with index data easily obtainable, and must be highly measurable and analyzable.

3 Case study

3.1 Analysis on eco-security status of Beijing Eco-Tech Development Zone(BEDZ)

Beijing Eco-Tech Zone is located at the boundary cross of Daxing, Tongzhou, and Chaoyang Disctricts. Its construction started on August 15, 1991. The BEDZ has braced four major industries: bio-engineering, new pharmaceutical, IT and electronics, equipment manufacturing, automobile production. As a key development area of Beijing in service of population evacuation and its new industry-centric town, it currently however, is restrained on land-use, limitation of water resource and eco-geological security conditions. Issues of resource preservation, pollution prevention, hazard prevention and disaster mitigation are growing imminent. Therefore it’s becoming ever important to screen out a reasonable and representative monitoring index after identification of the bottlenecks restricting the evolution of eco-system in the construction of BEDZ, then to design an eco-security monitoring program.

3.2 Framework of Eco-Security Monitoring Index System in the construction of BEDZ

3.2.1 Indexing system hierarchy

This paper, fully integrating the features of development zone and utilizing the P-S-R model, makes “Ecosystem Pressure” to pre-alarm “Resource Security”, “Ecosystem State” to represent “Environment Security”, and “Ecosystem Response” to safeguard “Social Security”. Total of 27 sub-indexes are selected to build the urban eco-security index hierarchy structure. See table2.

3.2.2 Index weighing

100 surveys were distributed to N.W. residential districts, S.W. industrial zone and partial east CBD of BEDZ, with 50% of surveyed being local employees, 20% of local students, 30% of local residents. The survey pertains to local residents’ requirement and evaluation of ecological resource, environmental and social aspects. Important assessments have been obtained through rating from the local population; for example, those surveyed generally believed that pressure of local water resource was greater than that of land and population; ratio of treatment on waste water and industrial steam was more important than per capita road area or number of public vehicles per ten-thousand people. Finally all ratings in each aspect by local residents were totaled and averaged which then were set as the basis for A-H-P analysis in comparison between one another; as a result, the judgment matrix is formed with following results, e.g. Table 1.

Table 1 Primary Index Weight

Ecological Security Comprehensive Index	Ecosystem Pressure	Ecosystem State	Ecosystem Response	Weight

Ecosystem Pressure	1	1 / 3	3	0.26
Ecosystem State	3	1	5	0.64
Ecosystem Response	1 / 3	1 / 5	1	0.10

The most prominent feature-vector is 3.0385， with CI 0.01925， RI 0.58， CR 0.03， CR<0.1. Results are deemed applicable after conforming test. The correlative feature- vectors are: （0.37， 0.91， 0.15） its relative weighs are（0.26， 0.64， 0.10）T after inductive calculation. Other weighing calculations are omitted here. The relative importance of each element from the same hierarchy to certain item in upper hierarchy is obtained through above comparisons, which then ratifies the weight of subject-hierarchy as to objective-hierarchy, factor-hierarchy as to subject-hierarchy, and index-hierarchy as to the factor-hierarchy. In the end, each hierarchy of index weight is multiplied to its upper hierarchy (all through subject-hierarchy), in order to calculate the weight of each hierarchy as to object-hierarchy. See Table-2 results, which show the weight of subject-hierarchy as to objective-hierarchy, factorial-hierarchy as to objective-hierarchy, index-hierarchy as to objective-hierarchy, e.g. Table 2.

Table 2. Index Weight System

Objective	Subject	Factor	Index
Urban eco-security Index Weight System	Ecosystem Pressure (P) (0.26)	Population Pressure (0.0325)	Population density (0.0065), Rate of natural population growth (0.0065), Rate of Urbanization (0.0195)
		Land Pressure (0.0325)	Per capita housing area (0.0140), Per capita road area(0.0140), Per capita public green area (0.0046)
		Water Resource Pressure(0.0975)	Per capita water resource (0.0731), Industrial waste water unit load (0.0244)
		Social Resource Pressure(0.0975)	GDP per capita (0.0497), Number of doctors for ten thousand people (0.0205), Public transport vehicles for ten thousand people (0.0068), Number of schools for ten thousand people(0.0205)
	Ecosystem State (S) (0.64)	Resource Quality(0.16)	Forest coverage rate (0.02), Green area coverage rate in developed zone (0.06), Rate of natural reserve area (0.02), Attainment rate of drinking water (0.06)
		Environment Quality (0.48)	Rate of hazard-free treatment of solid waste (0.0283), Rate of waste water treatment (0.1411), Rate of industrial steam treatment (0.1411), air quality comprehensive index (0.1411), Attainment rate of environmental noise (0.0283)
	Ecosystem Response (R) (0.10)	Intellect Capacity(0.025)	Number of college-graduates per ten thousand people (0.0208), Number of books for ten thousand people(0.0043)
		Investment Capacity (0.075)	Rate of investment in GDP on residence (0.0094), Rate of investment in GDP on environment (0.0281), Rate of investment in GDP on public services and facilities (0.0281), Rate of investment in GDP on technology (0.0094)

3.2.3 Results of eco-security monitoring index

Utilizing the weight calculations of Index hierarchy as to Objective-hierarchy mentioned above, and through the comparisons between weights as to their magnitude and basing on selection principles of monitoring indexes, as well as BEDZ's main eco-security issues, twelve items are screened out respectively: Rate of waste water treatment, Rate of industrial steam treatment, Air quality comprehensive index, Per capita water resource, Forestry coverage rate in developed zone, Attainment rate of drinking water, Rate of hazard-free treatment of solid waste, Attainment rate of environmental noise, Rate of investment in GDP on public services and facilities, Number of college-graduates per ten thousand people, Number of doctors for ten thousand people, Population density. Out of these 27 indexes, the first nine are higher in weight, and the last three are selected according to social practical issues for this development zone.

3.2.4 Eco-Security Monitoring Program(ESM)

The establishment of Eco-Security Monitoring Index System is only part of overall Eco-Security Monitoring. ESM includes monitoring and control. In order to carry through eco-security monitoring, 12 selected monitoring indexes are to be monitored and brought in statistics to integrate into the Monitoring-Control Program. Meantime, monitoring networks for air, water, noise, solid waste, eco-environmental quality and source of pollutants must be improved. Secondly, Control Systems must be developed and designed, including software development, system design, database design, system data collection, system implementation, web publishing and communication, and GIS technology integration, e.g., in Fig 2.

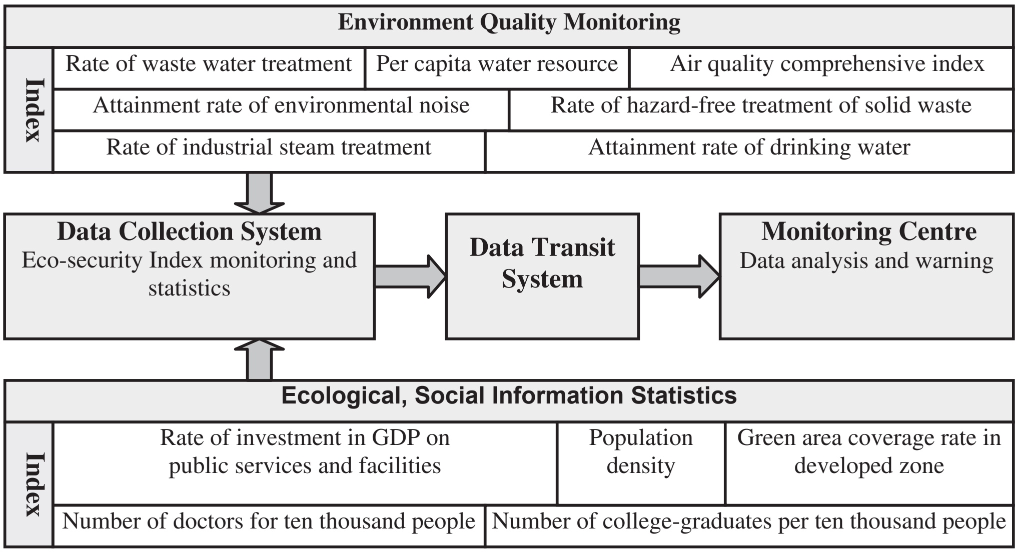

Fig 2 . Monitoring Program

4 Conclusions

The Eco-Security Index System is a crucial part for Eco-Security Monitoring Program of the urban development zone. P-S-R model can panoramically reflect the regional eco-security, so as to establish various key elements of the index system in three subsystems of economy, environment, and social metropolitan. Monitoring indexes must obtain data in real-time, cover large scopes, and be representative. Based on real circumstances during development zone construction, main environmental issues faced, ecological bottlenecks, as well as index data availability under consideration, this paper selected twelve items of eco-security indexes that are relatively operational, applicable to similar development zones. Combining the surveys that acquired public opinions on eco-security consciousness, then through A-H-P analysis, the weights are prioritized and make the selected indexes more objective and relevant to practical significance.

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